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MANAGEMENT AND ECOLOGICAL NOTE

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Evaluation of a novel mobile floating trap for collecting migrating juvenile eels, *Anguilla anguilla*, in rivers

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The recruitment of European eel *Anguilla anguilla* L. has plummeted during the last decades (Dekker, 2002), and the species is now considered critically endangered under IUCN criteria (Jacoby & Gollock, 2014). It is therefore of utmost importance for conservation incentives to enhance the success of naturally recruited juveniles, as reduced recruitment limits the natural production of mature silver eels. A substantial proportion of the glass eels and elvers reaching Western Europe after their travel across the Atlantic Ocean, migrate into rivers to forage, grow, eventually reach maturity and, as silver eels, return to the spawning grounds in the Sargasso Sea (Calles et al., 2010; Righton et al., 2016). Natural migration opportunities are restricted in regulated rivers, where juveniles are often trapped below the lowermost dam to be transported to and released at upstream rearing grounds. Trap efficiency may thus limit recruitment of mature silver eels in regulated rivers (Brämick, Fladung & Simon, 2016).

The eel ladder is one the most common and effective conventional trap designs for collecting juveniles in trap-and-transport stocking (Drouineau et al., 2015; Environment Agency, 2011; Knights & White, 1998; Podgorniak, Angelini, Oliveira, Daverat & Pierron, 2017). This trap design consists of an inclined ramp with wetted climbing substratum (e.g. eel tiles; Environment Agency, 2011, Vowles, Don, Karageorgopoulos, Worthington & Kemp, 2015) and a holding compartment for trapped eels (Solomon & Beach, 2004). To increase trap efficiency, water is often released at the entrance of the ramp to attract eels by means of turbulence and the sound of plunging water (Piper, Wright & Kemp, 2012). Entrance widths vary, but a typical eel ladder is commonly 0.5 m wide or narrower (Knights & White, 1998; Piper et al., 2012; Solomon & Beach, 2004). In regulated rivers, this type of trap may entail difficulties in, for example, finding the optimal position, integrating the trap into the dam, as well as adjusting the position of the attraction water to altering water levels. In this study, a novel, mobile, floating eel trap is described, and the results from an evaluation of the trap in two Swedish regulated rivers are presented. The mobile trap was designed to enable adaptive placement and to reduce the length of the climbing distance while maximising the width of the entrance. The trap was positioned near and compared to a conventional stationary eel ladder, fastened to the river bank (Figure 1).

The mobile trap consisted of two ramps of 0.5 m length and 2.4 m width, with the entrances positioned away from each other perpendicularly to the stream flow. The ramps were fastened to floating devices and held together by an aluminium frame (Figure 1; see online supplementary material for details; Figures S1-4). Pumped water (5 L/s) was released along the entire width of the entrances on both sides. Eels that climbed the ramps fell into a channel and were guided into a livewell located underneath the trap. The stationary trap used a ramp of 4.8 m length and 0.4 m width (Figure 1), and pumped water (5 L/s) was continuously released as a single spray near the entrance.

The ramps of both trap types (30° angle of inclination) were lined with climbing substratum (EF16™, Elghagen Fiskevård, Åstorp, Sweden) and covered with tarpaulin to protect against avian predators. Water, released at the top of the ramps, wetted the climbing substratum (0.08 L/s for the stationary trap; 1 L/s for the mobile trap). Owing to varying water levels in the rivers, the actual distance for the eels to climb in the stationary trap varied between 3.0 and 4.7 m. The varying water levels also altered the distance between the attraction water and the entrance of the stationary trap (between 0 and 0.4 m). The climbing distance in the mobile trap was always 0.4 m, and the attraction water was always released at the entrances.

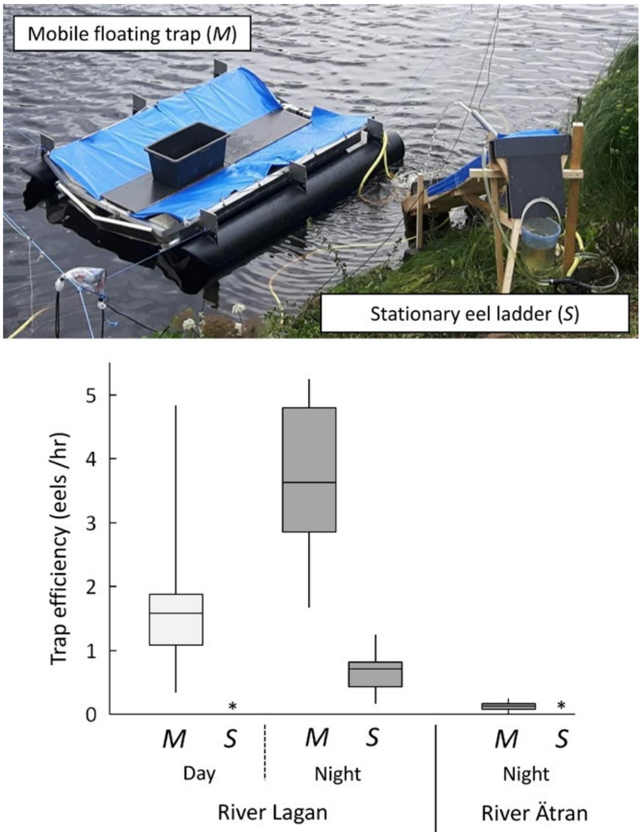

FIGURE 1 The efficiency of a novel, mobile, floating trap (*M*) for collecting juvenile eels *Anguilla anguilla* L. was compared to that of a conventional, stationary eel ladder (*S*) in two regulated rivers in Sweden. In the River Lagan, the traps were tested during eight days and ten nights; and in the River Ätran, the traps were tested during ten nights. In the upper photo, attraction water can be seen being released at the entrance of the stationary trap, whereas both entrance and attraction water are situated and released underneath the blue tarpaulin cover of the mobile trap. The lower panel shows the range, upper and lower quartile and median of caught juveniles per hour using the two types of traps in the two rivers. During the day, the eel ladder caught no eels in either river, which is indicated by asterisks. [Colour figure can be viewed at wileyonlinelibrary.com]

The traps were tested during the day (from 08:00 to 14:00) and at night (from 20:00 to 08:00) in the River Lagan (56°31′N, 13°03′E) between 18 and 28 July 2016. At night, the turbines of the hydropower plant were not in operation, resulting in zero discharge. Consequently, the traps were tested in still water at night in the River Lagan, whereas mean discharge during the day was 70 m^3/s, and water velocity at 20-cm depth near the entrances of the traps was 0.3 m/s. Water temperature during this study period ranged from 19 to 23°C. To evaluate the mobile trap in running water at night, the traps were moved to the River Ätran (57°02′N, 12°39′E, discharge = 13 m^3/s, water velocity at 20-cm depth = 0.2 m/s, water temperature range: 17–20°C) and tested between 4 and 18 August 2016 (from 20:00 to 08:00). With days and nights used as replicates, the two trap types were compared using three separate paired Wilcoxon signed-rank tests for the daytime trial in the River Lagan and for the night-time trials in the rivers Lagan and Ätran, respectively.

In the River Lagan, the mobile trap caught 3.7 ± 0.4 eels/hr (mean ± 1 *SE*) at night and 1.8 ± 2.9 eels/hr during the day, whereas the stationary trap caught 0.7 ± 0.03 eels/hr at night and no eels during the day. In the River Ätran, fewer eels were collected, and the mobile trap caught 0.13 ± 0.03 eels/hr, whereas the stationary trap caught no eels (Figure 1). Mean eel total lengths were 70 mm (minimum–maximum = 60–100 mm). Pairwise comparisons of the traps revealed that the mobile trap caught more juvenile eels than the stationary trap in all three trials (Lagan, night: $Z = 2.52$ $p = .012$; Lagan, day: $Z = 2.81$, $p = .005$; Ätran, night: $Z = 2.81$, $p = .005$).

The mobile trap outperformed the conventional eel ladder in this study, a result likely attributed to the wide and short ramps of the mobile trap. The rate of total released water (for wetting the climbing substratum and for attraction) was higher at the mobile trap (6 L/s) than at the stationary trap (5 L/s), which also could have played a minor role in the difference in trap efficiency. In contrast to the stationary eel ladder, the mobile trap is not constrained by the need to be integrated into or attached to the barrier or the river bank, allowing wide and short ramps. Additionally, the mobility may enable managers to search for the spatial optimum for trapping efficiency of juvenile eels. This possibility may have large effects on the number of collected eels, because they are often heterogeneously distributed downstream dams, both spatially and temporally (Harrison, Walker, Pinder, Briand & Aprahamian, 2014; Piper et al., 2012). Furthermore, it is possible that the locations with the highest eel densities are only accessible for a floating trap. A potential limitation of the current design of the floating trap is that requires manual emptying. Hence, a floating trap, used for passage of juvenile eels at, for example, a low-head dam, would need to be combined with an automatic emptying procedure (e.g. by means of a venturi pump system; Armstrong et al., 2004) and a passage route.

To improve the situation for the threatened European eel in regulated rivers, better methods need to be developed that more efficiently collect and transport juvenile eels past dams. The mobile, floating trap described in this study may be one step towards this goal.

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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